LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the twentieth of the preceding month; for the second issue, the fifth of the month. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Gamma-Rays from Nitrogen Bombarded with Deuterons

It is known[1] that nitrogen bombarded with deuterons yields several homogeneous groups of alpha-particles, and at least two groups of protons. The reactions are probably

$$N^{14}+H^2\rightarrow C^{12}+He^4, \quad (1)$$
$$N^{14}+H^2\rightarrow N^{15}+H^1. \quad (2)$$

Lawrence, McMillan and Henderson[2] have investigated the alpha-particle spectrum down to about 6-cm range, and the proton spectrum down to about 10-cm range. From the differences in energy of the particle groups found, they inferred that there are excited levels of 3.8 and 4.7 MEV associated with the alpha-particle emission, and a level of 4.7 MEV associated with the proton emission. It should be kept in mind that in reaction (1), as far as the experimental data are concerned, the excited levels could be either in the C^{12} or in the alpha-particle.

We have studied the gamma-radiation emitted from nitrogen bombarded with deuterons, by means of a cloud chamber. Fig. 1 shows the energy spectrum of recoil electrons obtained from 2400 photographs taken at 900 kv bombarding voltage, 80 microamperes deuteron current and 1500 gauss magnetic field. The target used was ammonium chloride, and to minimize chemical decomposition it was bombarded only for about $\frac{1}{2}$ second, at the time of each expansion of the cloud chamber. In order to increase the resolution in the spectrum, only those tracks making angles less than $7\frac{1}{2}$ degrees with the direction of the radiation were recorded. The intercepts in the electron energy spectrum (shown as dotted lines), after having 0.2 to 0.25 MEV added to them in accordance with the theory of Compton collisions, indicate that the principal gamma-ray lines are 1.9, 3.1, 4.0, 5.3 and 7.0 MEV.

It is seen that these gamma-ray lines (except the 4 MEV line) do not represent directly the differences between the total energy released in the reaction and the energies of the various particle groups. They would represent these differences only if the excited nucleus could make no other transition than to the ground state; if transitions to intermediate levels are permitted, which is reasonable to expect, the gamma-rays observed will be related, but not in a direct way, to the energies of the particle groups. To correlate the gamma-rays and particles in the present case it is easy to construct simple level diagrams which are consistent with the data, but it is of course not possible to make one that is unique, on the basis of the present incomplete data. The alpha-particle energies indicate levels at 4.7 and 3.8 MEV, and the gamma-ray energies indicate, in addition, a level at 7, and possibly one at 5.3 MEV. The group of alpha-particles corresponding to the excitation of the 7-MEV level would be expected to have a range, in Lawrence, McMillan and Henderson's experiment, of 4.5 cm, which is considerably below the region for which they give data. The group corresponding to the 5.3 MEV level would have a range of 6.2 cm, and would lie just at the lower limit of their curve.

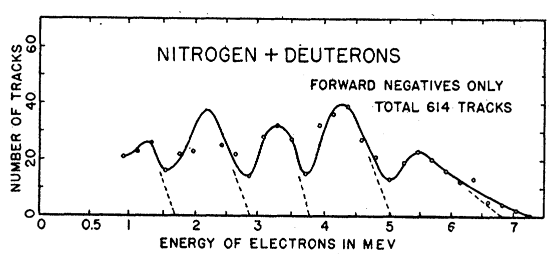

FIG. 1. Energy spectrum of recoil electrons produced by the gamma radiation from nitrogen bombarded with deuterons.

The height of the potential barrier which keeps the excited C^{12} from splitting up into three alpha-particles, or into one alpha-particle and Be^8 does not necessarily constitute a limitation upon the energy to which C^{12} may be excited. The excitation may be thought of as being within one of the constituent alpha-particles, and indeed the high observed value of the excitation (7 MEV) inclines one toward this view. One does not know how much different the levels in such a bound alpha-particle would be from those in a free alpha-particle; if they are nearly the same, the question of whether the observed excitation is in the C^{12} or in the ejected alpha-particle will be difficult to answer, on the basis of the present measurement of the gamma-ray energies. If both kinds of excitation occur, however, one might expect to find doublet structure in the alpha-particle energy groups, one member of each doublet corresponding to the excitation of a level in a bound alpha-particle, and the other to the excitation of the corresponding level in the ejected alpha-particle.

The number of protons emitted in reaction (2) is roughly a thirtieth of the number of alpha-particles from reaction (1), and therefore the contribution to the gamma-ray spectrum from this source can be neglected.

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[1] Lewis, Livinston and Lawrence, Phys. Rev. **44**, 55 (1933).
[2] Lawrence, McMillan and Henderson, Phys. Rev., **47**, 273(1935).